USER'S GUIDE

Demonstration of a Fractured Rock Geophysical Toolbox (FRGT) for Characterization and Monitoring of DNAPL Biodegradation in Fractured Rock Aquifers

ESTCP Project ER-201118

JANUARY 2016

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01/01/2016	Guidance	July 2011 - January 2016

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Demonstration of a Fractured Rock Geophysical Toolbox (FRGT) for Characterization and Monitoring of DNAPL Biodegradation in Fractured Rock Aquifers	W912HQ-11-C-0027
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
F.D. Day-Lewis, C.D. Johnson, J.H. Williams, C.L. Boyden – USGS; L.D. Slater; J.D. Robinson - Rutgers University	ER-201118
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Rutgers University, 101 Warren Street, Newark, NJ 07102 USGS, 12201 Sunrise Valley Drive, Reston, VA 20192 Pacific Northwest National Laboratory, 902 Battelle Blvd, Richland, WA 99352	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
Environmental Security Technology Certification Program Program Office 4800 Mark Center Drive Suite 17D03 Alexandria, VA 22350-3605	ESTCP
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

N/A

14. ABSTRACT

Our overarching goal is to advance the cost-effective, appropriate use of geophysical technology in fractured rock. Specifically, we envision the FRGT-MST (1) equipping remediation professionals with a tool to understand what is likely to be realistic and cost effective when contracting geophysical services, and (2) reducing misguided, money-wasting applications of geophysical methods at sites where those methods are doomed to failure.

15. SUBJECT TERMS

DNAPL biodegradation charactrization and monitoring, remediation, fractured rock aquifers.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	UU	UL	6	

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

INTRODUCTION

Geophysical technologies have the potential to improve site characterization and monitoring in fractured rock, but the appropriateness and effectiveness of geophysics at a particular site depends strongly on project goals (e.g., identifying discrete fracture zones, mapping hydraulic properties, tracking contamination or remediation efforts, etc.) and site characteristics (e.g., lithology, depth to bedrock, presence of infrastructure). No method works at every site or for every goal. New approaches are needed to identify the set of geophysical methods appropriate to project goals, their likely effectiveness given site conditions, and practical cost considerations given project budget constraints. To this end, we present the Excel-based Fractured-Rock Geophysical Toolbox Method Selection Tool (FRGT-MST). Our overarching goal is to advance the cost-effective, appropriate use of geophysical technology in fractured rock. Specifically, we envision the FRGT-MST (1) equipping remediation professionals with a tool to understand what is likely to be realistic and cost effective when contracting geophysical services, and (2) reducing misguided, money-wasting applications of geophysical methods at sites where those methods are doomed to failure.

APPROACH

The FRGT-MST is a user-friendly Excel-based software (**Figure 1**) for identification of the set of geophysical methods likely to be appropriate and effective for a given set of project goals based on site conditions. The ‘toolbox’ comprises 30 different geophysical methods divided into 4 categories: surface, cross-hole, borehole, and hydrologic. The user enters information in two tables (1) project and site parameters, including budget level; and (2) project goals (**Figure 2**). A third table is populated with indicators for whether each method could potentially support any of the specified goals, and whether each method is likely to work at the site described (**Figure 2**). The suite of potentially suitable methods is thus the intersection of the sets of appropriate and feasible methods.

Excel conditional formatting is used throughout the spreadsheet, coded based on simple rules of thumb and common-sense constraints for experiment design. For example:

- the feasibility of borehole optical televiewer requires that borehole fluids are not muddy/opaque;
- the feasibility of borehole radar requires that boreholes are open or PVC-cased; and
- the feasibility of crosshole methods with sufficient resolution generally requires well aperture (vertical:horizontal imaging area) >1.5.

Excel conditional formatting is also coded to identify which methods support specified project goals. For example,

- ERT is appropriate technology for time-lapse monitoring;
- surface seismic is appropriate technology for mapping depth to bedrock; and
- focused packer testing is appropriate technology for measuring small-scale hydraulic properties.

A series of 30 worksheet appendices are provided in the FRGT-MST, each with information on a different method from the toolbox (**Figure 3**). The appendices are hyperlinked from the table of methods in the FRGT MATRIX worksheet (**Figure 2**). Appendices provide basic information on the various methods—a key reference and several graphics showing the instrumentation and (or) example results. The appendices are intended to provide overviews rather than in-depth information.

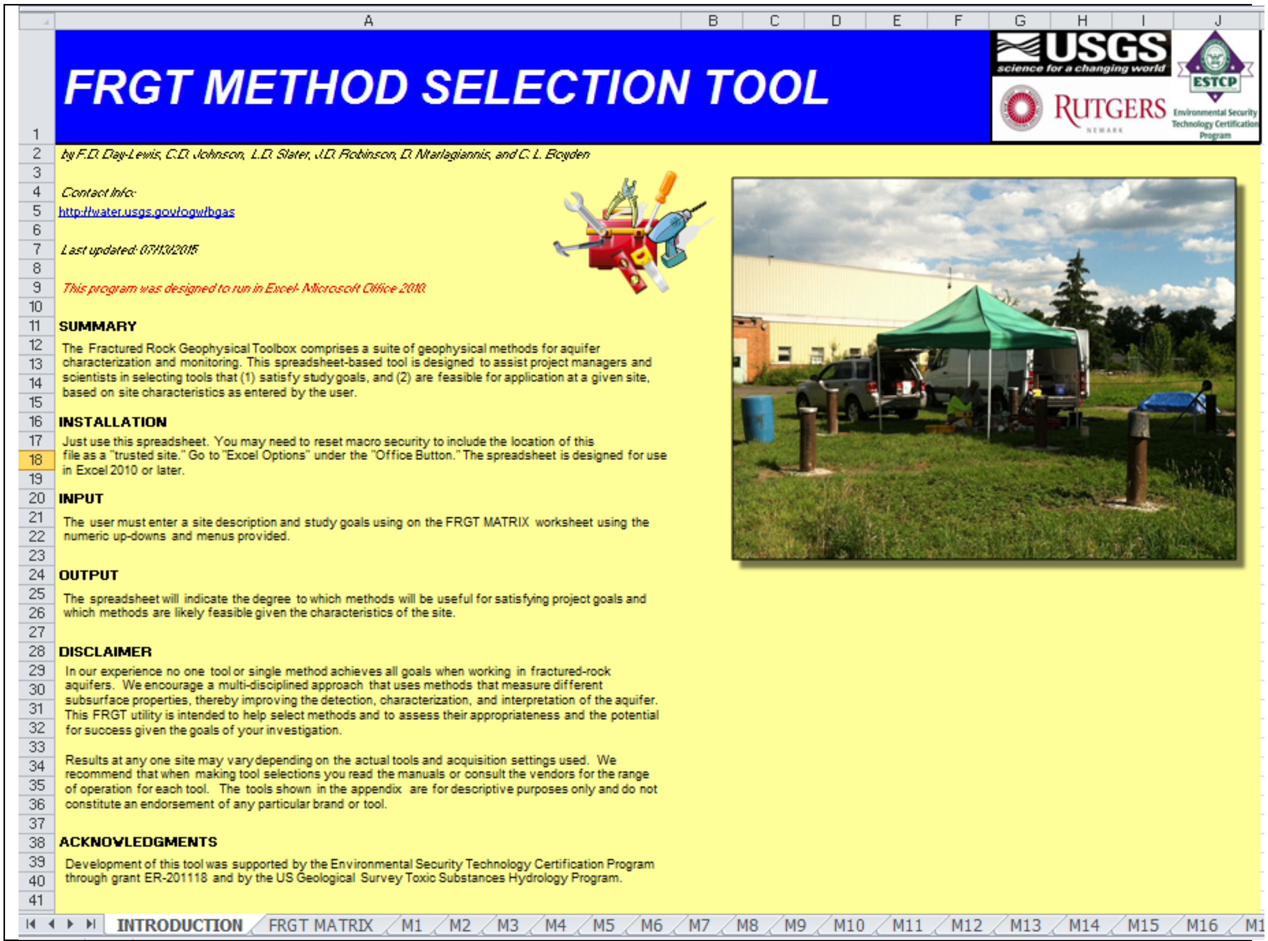

Figure 1. FRGT INTRODUCTION worksheet which provides background information and instructions for the use of the FRGT-MST.

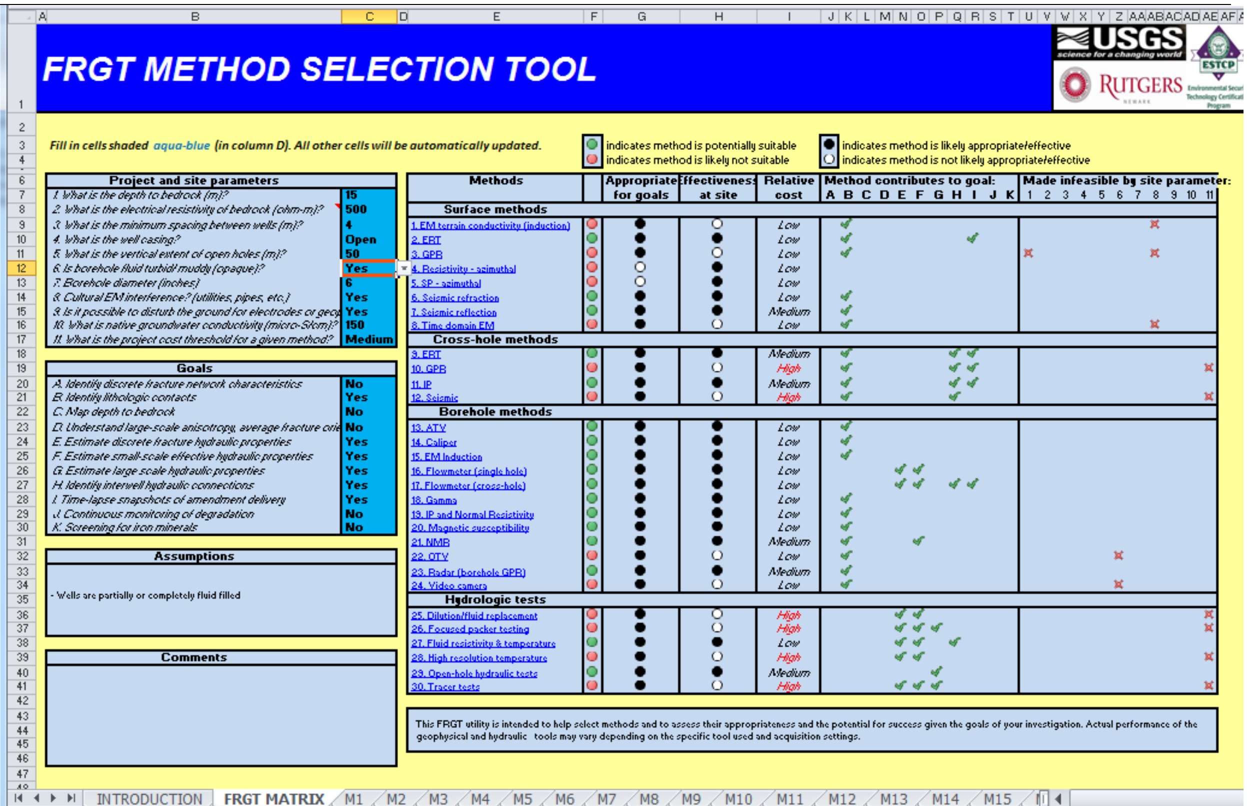

Figure 2. FRGT MATRIX worksheet, where the user enters project/site parameters and goals and the output table is generated showing which methods are likely feasible for the site and appropriate to specified goals. Method satisfying both feasibility and appropriateness conditions are indicated by 'green lights' in column F, whereas methods that are infeasible or inappropriate are indicated by 'red lights.'

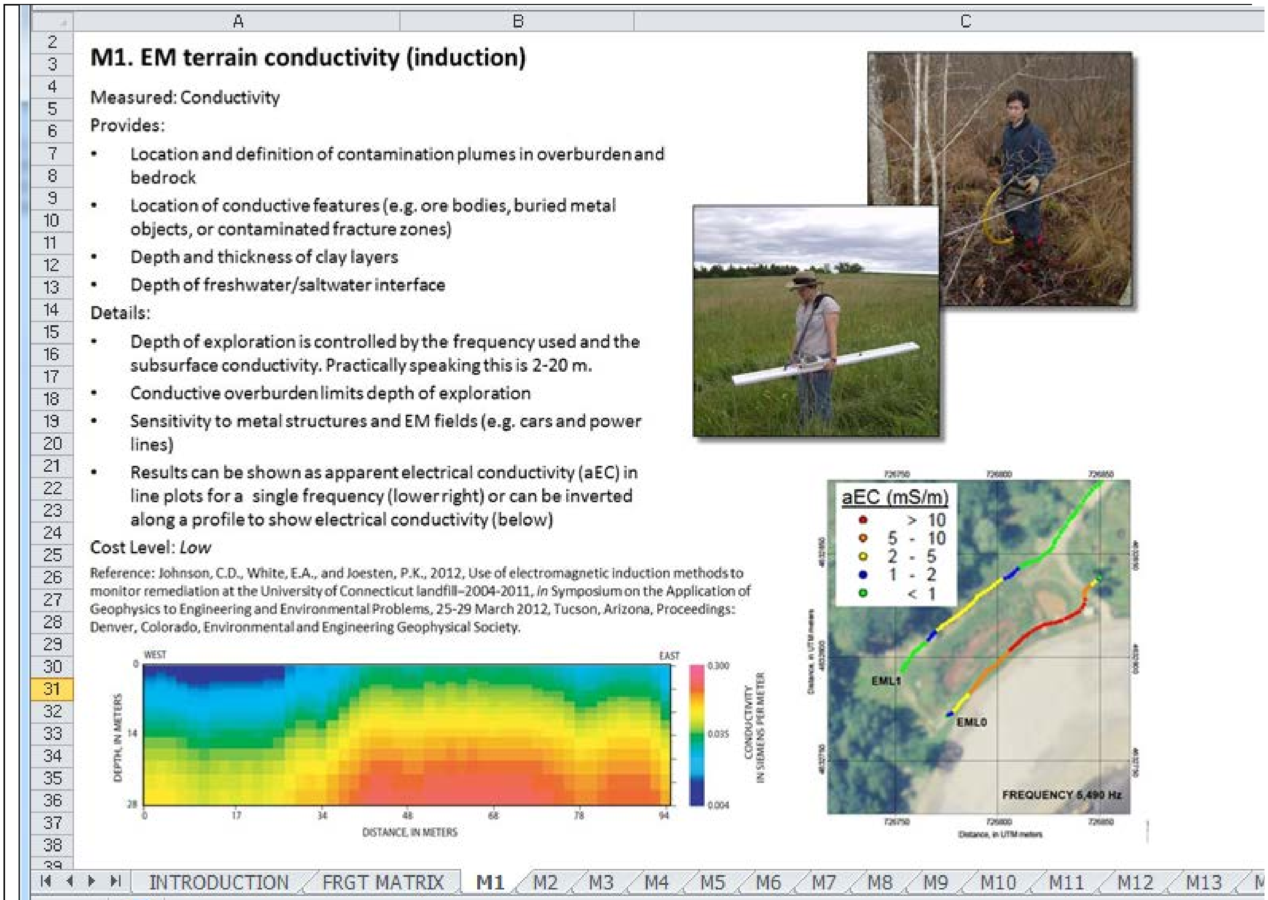

Figure 3. Worksheet appendix M1, providing an overview of surface-based electromagnetic terrain conductivity.

EXAMPLE

The distributed FRGT-MST Excel file reflects project parameters/goals and site characteristics for the U.S. Geological Survey research site at the Naval Air Warfare Center (**Figure 4**). The results of the spreadsheet analysis correctly indicate that (1) borehole and cross-hole radar methods are unlikely to work at the site, and (2) borehole gamma and electromagnetic methods are likely to work and also support project goals. In this case, these recommendations are based on relatively simple site geological information, in addition to the project goals, provided by the user.

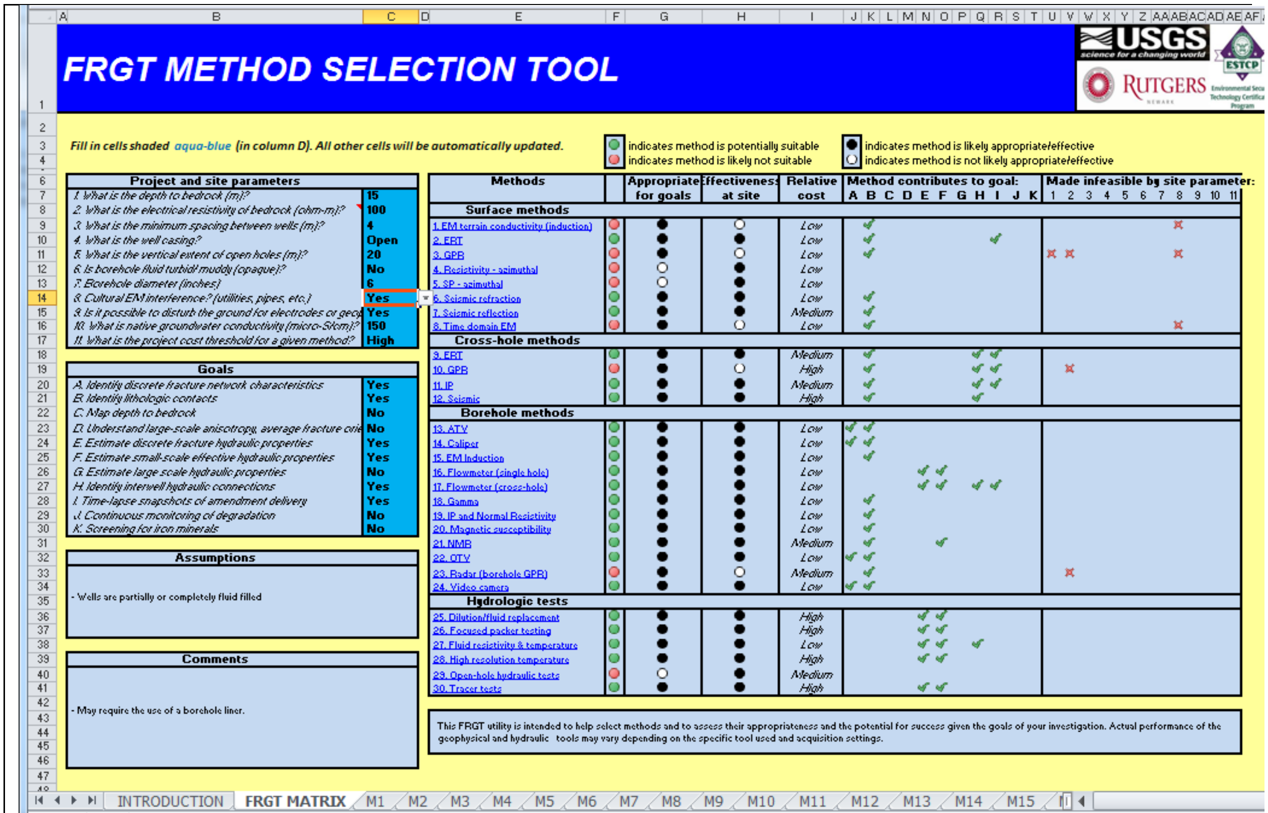

Figure 4. FRGT Matrix with inputs and output for the U.S. Geological Survey research site at the Naval Air Warfare Center in West Trenton, NJ.

DISCUSSION AND LIMITATIONS

We encourage users to look at the equations used throughout the spreadsheet to gain insight into experiment-design parameters and the potential uses of various methods. We stress that the FRGT-MST is, necessarily, a simple tool and like any tool, its capabilities are limited. The results of the spreadsheet analyses are not the official recommendations of USGS or Rutgers. The USGS and Rutgers provide no warranty, expressed or implied, as to the correctness of the furnished software or the suitability for any purpose. The software has been tested, but as with any complex software, there could be undetected errors. Users who find errors are requested to report them to the Dr. Frederick Day-Lewis (USGS) at daylewis@usgs.gov.

AKNOWLEDGMENTS

The development of the FRGT-MST was supported by ESTCP grant ER-201118.